BIOLOGICAL RESOURCES OF THE SAN FRANCISCO BAY/ SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

FACTORS AFFECTING: WILDLIFE AND PLANT RESOURCES OF THE SAN FRANCISCO BAY/ SACRAMENTO -SAN JOAQUIN DELTA ESTUARY

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FACTORS AFFECTING WILDLIFE AND PLANT RESOURCES IN THE SAN FRANCISCO BAY AND SACRAMENTO-SAN JOAQUIN DELTA

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FOREWORD

The following discussion provides a profile of factors affecting wildlife and plant resources in the Estuary. This paper is, and should be considered, a companion to the report; "Status and Trends: Wildlife and Plant Resources in the San Francisco Bay and Sacramento-San Joaquin Delta".

More detailed discussions of the factors outlined in this report may be found in two reports issued by the San Francisco Estuary Project (SFEP): "Status and Trends Report on Wildlife of the San Francisco Estuary" and "Status and Trends Report on Wetlands and Related Habitats in the San Francisco Estuary".

The BDOC may also be interested in the "Delta Wildlife Habitat Protection and Restoration Plan" (1980 Madrone Associates), and the "Plan of Protection for the Suisun Marsh" (1984 DWR).

INTRODUCTION

The purpose of this report is to provide a narrative description of the major factors which influence abundance and distribution of wildlife and plant communities within the Estuary. This report discusses: factors affecting abundance and distribution of waterfowl and other wildlife species in the Estuary; impacts on wetlands and other associated communities that are critical to the perpetuation of shorebird and waterfowl resources; and the population status of the Estuary's special status birds, mammals, amphibians, reptiles, invertebrates, and plant resources.

As a result of destruction and degradation of habitat, through a variety of direct and indirect human impacts including habitat alteration and degradation, agricultural practices, water flow alterations, water quality, flood control and levee projects, pollutants, and hunting, a wide variety of species populations have declined substantially in numbers and distribution throughout the Estuary. Some of these effects have been ameliorated to some extent by the substitution of agricultural habitat for native habitat and the creation of managed waterfowl habitats.

BIRDS

WATERFOWL

The San Francisco Bay/Sacramento-San Joaquin Delta Estuary is an extremely important habitat for waterfowl. Areas of heavy migratory waterfowl use in the Delta include Rindge, Empire, Webb, and MacDonald tracts, and Staten, King, Venice, Mandeville, Medford, and Quimby islands (Madrone Assoc. 1980). The distribution of waterfowl populations within the Estuary is influenced by weather changes including drought, water conditions, and food availability. Recent declines in the waterfowl population have primarily been attributed to the combined effects of drought, habitat alteration and degradation, agricultural practices, trace element contaminants, and predation within both wintering and nesting grounds.

Agricultural irrigation and the periodic flooding of fields for leaching of accumulated salts, pest control, or wildlife habitat management create the most significant demands within the Delta for water withdrawals. The amounts of water used locally vary with the types of crops being grown, the time of year, the weather, etc. Average annual withdrawals for agricultural purposes, including seepage as well as pumped water, have been estimated at 980,00 acre-feet, most of which is used in the summer (June-September). Duck clubs in the Sacramento-San Joaquin Delta fill their ponds in late September and early October, creating essentially the only ponded areas in the Delta during that period.

Habitat Alteration and Degradation

The Estuary's waterfowl populations are influenced by the availability and quality of habitat. Waterfowl habitat varies greatly from year to year, depending on precipitation, agricultural practices, and human disturbances (SFEP 1991a).

Unusually wet years can change waterfowl movement patterns within the Estuary. Waterfowl tend to leave Suisun Marsh, Napa Marsh, and San Pablo Bay and move into the Delta and other areas when rains begin. If winter rains are late, large numbers of waterfowl remain in the Suisun Marsh. This movement, in response to increased water on land surfaces, also is seen when large numbers of birds move from Suisun Marsh to the Delta when farmers begin to flood their agricultural fields (USFWS 1978).

Shorebirds and ducks migrating south are attracted to agricultural fields that are flooded in the late summer and fall. These fields are typically flooded for a day or two with shallow water to control weeds and centipedes, and provide resting and feeding habitat for the migrant birds. Canada geese, tundra swans, and large numbers of ducks are attracted to fields that are flooded for several months during the winter for leaching or to create waterfowl habitat, and to areas flooded by ponded rainwater

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and unpumped seepage. The number and location of flooded fields in the Delta varies from year to year, depending on the year's weather and current leaching practices. Increased salinity of Delta water would limit the winter leaching of fields, reduce the amount of waterfowl habitat, and cause a shift to more salt tolerant crops than corn, which generally have less wildlife food value.

For migrating waterfowl, the nesting and migratory areas outside the Estuary, and wintering habitats used for up to eight months each year within the Estuary, are critical. The availability and quality of wintering habitats are major influences on the breeding productivity of waterfowl. Degradation of wintering habitat can contribute to poorer health or "body condition" for waterfowl nesting in the spring. The quantity and quality of wintering habitat in the Estuary, and its effect on the condition of waterfowl during spring migration, may be the most important factors limiting waterfowl populations during years when there are good breeding ground conditions (USBR 1986).

The wintering waterfowl of the Estuary can be considered part of the Central Valley waterfowl population because regular movement occurs between the two regions. Agricultural, municipal, and industrial development in the Central Valley are reducing waterfowl habitat to small, highly "clumped" areas which are merely agriculturally dependent remnants of once very productive areas (Gillmer et al. 1982). Habitat loss forces wildlife to become concentrated within smaller areas, leading to overcrowding and poor nutrition resulting from inadequate and scarce food supplies. This, in turn, lowers resistance to and increases vulnerability to contaminants and disease (avian cholera, avian botulism). Predation losses also increase as the population becomes more concentrated and the overall health of the waterfowl decreases.

Degradation and loss of habitat such as wet grasslands, pastures, crop lands, meadows, fresh water emergent wetlands, and small lakes, both within and outside the Estuary, continues today. This has resulted in the reduction or elimination of roosting and foraging habitat for tule geese and Pacific greater white-fronted geese, snow geese, Canada geese, and dabbling ducks.

Agricultural Practices

Agricultural production within the Estuary provides habitat for wintering and nesting waterfowl. Based on National Wetland Inventory data, farmed wetlands in the Bay total approximately 35,400 acres, with 25,828 acres (73 percent) in the North Bay and 8,263 acres (23 percent) in the Suisun Marsh. In the Delta, over 530,000 acres of present agricultural lands were formerly tidal wetland habitat.

These lands now support a variety of crops and pasture and function as

seasonal farmed wetlands when they are flooded in winter. Their value to wildlife depends on each site's vegetational characteristics, cultivation practices, and flooding regimes.

Waterfowl of the Pacific Flyway use grain fields (corn, sorghum, wheat) for fall, winter, and spring resting and feeding habitat. The suitability of winter habitat is a limiting factor for many Pacific Flyway waterfowl and shorebird populations. The amount of waterfowl use varies with the type of crop grown and management practices utilized, such as flooding of fields for weed control or leaching.

Shallow, flooded fields provide resting and feeding habitat for migratory birds, as do other areas that become flooded from ponded rainwater or groundwater seepage. Wildlife habitat in the Estuary thus is enhanced as a result of the practice of flooding fields in winter to leach out salts and control weeds and insects. Corn is probably the most valuable crop to waterfowl. It is also the most salt-sensitive crop, requiring the most regular leaching (Rollins 1977).

From mid-December into March, as much as 25 percent of the Delta's total area may provide ponded water or wet soil conditions that serve as habitat for many shorebirds and waterfowl. Additionally, white-fronted, snow, and Ross geese extensively use unflooded fields of harvested corn and milo as habitat.

Though much of the Estuary has been converted from natural habitat to agricultural land, migratory waterfowl remain dependent on these lands for food resources. Geese feed on germinating grain, tundra swans often feed on waste corn, and mallards and pintails commonly feed in both harvested and unharvested wheat fields. These crops are an important energy source, although the primary sources of protein needed during molt and egg production are probably invertebrates and native wetland vegetation (USBR 1986). Waterfowl such as green-winged teal, cinnamon teal, northern shoveler, gadwall, and diving ducks have not adapted their feeding habits as effectively to agriculture (SFEP 1991a).

Several advances in agricultural practices have adversely affected waterfowl and other wildlife species populations. For example, more efficient farming has produced less wasted grain, fewer weed seeds, and less cover for wildlife. This results in a more restricted diet and less food for wildlife, especially for waterfowl during fall and spring. Furthermore, land leveling to help manage water more efficiently reduces food abundance, nesting cover, and habitat diversity. Leveled fields drain more rapidly and support fewer wetland plants. Other farming practices, such as repeated discing, plowing, mowing, burning, and haying, limit the ability of wintering and nesting waterfowl to use these lands as habitat (SFEP 1991a).

Long-range problems threatening the future of agriculture in the Delta also threaten the future of wildlife habitats symbiotically associated with Delta agricultural

lands. Technical and economic problems could reduce the extent of farming in some parts of the Delta; current management policies or crop selection may need to be altered and, potentially, farming may become marginal or impossible in some locations (Madrone Assoc. 1980). Major areas of concern include:

Irrigation and leaching --

Because the water table is quite close to the soil surface in the Delta, subirrigation (using the natural rising of groundwater) has been the most practical method of applying water to crops. As most islands' elevations are below-sea level, pumps must be in almost constant operation to maintain a desirable water table elevation in island interiors. As energy costs rise, this becomes increasingly problematic. Both the region's peat soils and subirrigation practices contribute to increasing soil salinity in the Delta. Through subirrigation, salts left behind by evaporation and transpiration accumulate and become more concentrated. Moreover, drainage waters increase salinity in surrounding sloughs and waterways, which exacerbates channel water salinity levels. If water quality is degraded by excessive agricultural return waters from Delta islands, combined with salt intrusion from the Bay, more frequent leaching will likely be required. As described earlier, increased salinities in Delta water and soils affect the types of crops grown, which in turn affect wildlife use.

Levee stability --

Levee maintenance problems are of critical importance to continued agricultural production throughout the Delta and preservation of significant areas of wildlife habitat.

Crop Selection --

Economic influences are reflected in crop selection, which responds to market demand. The change in crop predominance (principally corn and other grains) in the Delta over the past 20 years has increased waterfowl use of the area (Rollins pers. comm, Madrone Assoc. 1980). A shift in cultivation costs or market demand could dictate a shift to crops with less wildlife food value than corn, milo, or wheat and seriously affect waterfowl populations.

The Department of Water Resources' (DWR) current Winter Grain Shift Program is intended to save water by shifting away from crops requiring spring and summer irrigation (e.g., corn) and use that "freed-up"water to help meet

export demand and Delta and Suisun Marsh water quality standards by supplementing Delta outflow. However, wildlife populations may be negatively impacted by changes in farming practices resulting from the crop shift program. Some of the problems that may adversely affect bird species include loss of corn forage and a loss of irrigated summer fields. If large parcels of Delta lands participate in the winter grain shift program, cumulative impacts to wintering waterfowl could be severe.

Clean farming and harvesting efficiency --

Removal of vegetation from irrigation ditches and brush along field margins to enlarge areas for cultivation may maximize crop production, but it also removes valuable wildlife cover and food sources. This is true for riparian vegetation and any brushy cover adjacent to agricultural lands. Currently there is no economic incentive for Delta farmers to maintain this habitat or other ruderal (weedy, scrub) lands, possibly excepting farms that are also managed as hunting clubs.

Current harvesting equipment cuts grain close to the ground, leaving little stubble for cover and reduced amounts of waste grain for wildlife. Widespread use of such equipment could have a serious detrimental effect on wintering waterfowl habitat.

Water Diversions and Water Quality

Levee failures, extensive irrigation diversions, and increased water diversions from and within the Delta have the effect of allowing further encroachment of saline water into the Delta.

Increases in Delta water and soil salinities affect the types of crops grown, which in turn affects wildlife use. Corn, for example, which is extremely important to wintering waterfowl, is one of the most salt sensitive crops. Barley and other more salt tolerant crops have significantly less value as waterfowl food. Consequently, a reduction in corn production would result in a diminution of overall food supplies for wildlife as well. The State Water Resources Control Board has adopted standards intended to guarantee, at a minimum, water quality better than that required to grow corn in the Delta. This demonstrated link between corn production and its support of wintering wildlife habitat makes it all the more important that future standards continue to guarantee water quality sufficient to support corn production on Delta Islands.

The variability of salinity distributions within the Estuary, caused in part by

increased freshwater diversions from the Delta, is of particular concern in wetland habitat areas where significant adverse impacts to wildlife may result from highly concentrated salinity levels that negatively affect wetland viability. An example of one such area is the Suisun Marsh. It is the largest diked seasonal wetland in the Estuary, comprising more than 57,310 acres. Salt water intrusion into the upstream reaches of Suisun Bay could lead to conversion of the remaining tidal brackish marsh into tidal salt marsh. Already, recent increases in salinity levels in the Suisun Marsh have made it difficult to maintain brackish marsh plant species that make Suisun Marsh such a valuable wintering habitat for waterfowl.

The majority of the vegetation within Suisun Bay is made up of tules, cattails, baltic rush, brass buttons, and fat hen; followed in concentration by salt grasses and pickleweed, and areas of alkali bulrush and barley. Most areas are flooded in the fall and drained in spring. In general, average soil water salinities in the marsh are increasing due to factors such as timing, duration and quality of water available for flooding, and the State, Federal and other water projects' reduction of the Marsh's freshwater inflow from the Delta (SFEP 1991b). Although, the conversion to salt marsh may provide improved conditions for some salt marsh dependent wildlife species, such as the California clapper rail, populations of fresh and brackish water dependent species, such as nesting populations of dabbling ducks and certain native aquatic life, would decline (USFWS 1990).

During drought years, waters with higher salt concentrations linger in Delta channels and adversely affect aquatic flora of marsh waterways and lands. In 1977, the driest year on record, marsh waterfowl food production was only about 25 percent of normal, and tidal marsh vegetation could not survive in most areas of Suisun Marsh (DWR 1984). Unless water of adequate quality is provided, and more intensive water management practices adopted, many managed wetlands will experience a reduction in waterfowl food plant production, causing waterfowl and other wildlife species losses. During drought conditions the areas most likely to be adversely affected are those with poor water control facilities, poor management practices, and a highly saline water source.

The "Suisun Marsh Plan of Protection" (SMPP) was developed by DWR, in cooperation with the U.S. Bureau of Reclamation, the Department of Fish and Game, and the Suisun Resource Conservation District, to address salinity and waterfowl issues. Managers of Suisun Marsh waterfowl habitat support continued implementation of the SMPP to ensure salinity levels adequate to maintain suitable waterfowl habitat.

In addition to salinity changes, water diversions influence rates of erosion along the shoreline habitat of some channels in the South Delta. While severe erosion may only occur in short stream segments, it may induce altered flow patterns, in turn creating barriers to the movement of aquatic organisms, decreasing instream habitat

diversity, and degrading water quality.

The formation of tidal marshes along the edges of San Francisco Bay has been dependent on sedimentation. The primary source of sediment is drainage from the Sacramento-San Joaquin basin, which currently supplies 80% to 90% of the total annual input. The amount of sediment entering the Estuary can be correlated with total Delta outflow (Krone 1979) and with the magnitude of peak flood flows. If these "sediment loads" decrease in the future as a result of a higher level of flood regulation or from altered water supply operation of the Delta tributaries, the accompanying decreased sedimentation rate may measurably reduce the rate of tidal marsh formation.

Flood Control and Levee Projects

Flood control and levee maintenance are of extreme importance in both destroying habitat and in protecting habitat. Downstream flooding in the Bay has been reduced by spreading and detaining flood flows before they enter the Bay. These flood flow retention areas provide habitat for migrating waterfowl. Portions of the Delta which divert and store floodwater from the Sacramento River during peak winter and spring runoff, such as Yolo Bypass, serve this function (Warner and Hendrix 1985), and then are farmed after drying (SFEP 1991b).

Extensive levee construction, particularly along the Sacramento River, has decreased the natural floodwater retention capacity of the riverine/floodplain system. Within the Delta, winter floodwater is heightened as greater volumes of floodwater are confined to the main river system, creating increased pressures on the levee system itself. Failures of levees protecting Delta islands have illustrated the need for more substantial flood control projects. A combination of upstream diversion and storage of streamflows has greatly reduced the volume and timing of freshwater flows and with them the transport of sediments and nutrients that feed downstream wetland habitats and overflow areas.

Levee construction and maintenance are the most influential factors relative to shaping and, in part, determining the type and condition of fish and wildlife habitat to be found in the Delta. This is especially the case for waterfowl habitat. Without the existing levee system, the value of the Delta to wintering waterfowl would be substantially reduced.

SHOREBIRDS

Habitat Alteration and Degradation

Seasonal wetlands, which have been severely reduced as a consequence of

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development pressures, are extremely important in the maintenance of shorebird populations. Seasonal wetlands are critical because they provide essential feeding, nesting, and resting habitat at a time of year when California's limited wetland acreage must support a very large bird population. Shorebirds rely on high areas or transitional areas during high tide for their loafing and foraging habitat. As an alternative to mudflats, seasonal wetlands provide such habitat.

The loss of seasonal wetland habitat has occurred without the benefit of monitoring affected wildlife populations, making it difficult to assess impacts to shorebird populations. However, seasonal wetland losses likely have resulted in the elimination of some high tide roosting and feeding areas and consequently a decrease in the number of shorebirds the Estuary can support (Stenzel and Page 1988). If projected seasonal wetland losses resulting from urban growth or other land conversions become a reality, accompanying reductions in populations of migratory shorebirds and other waterbirds are highly probable.

Other wetland habitat types in the Estuary also are crucial to shorebirds: 1) Managed wetlands -- refuge and private lands that are flooded in winter to provide waterfowl habitat and drawn down in early spring for the growth of agricultural food plants; 2) Rice fields -- intentionally or naturally flooded in winter, drained in early spring, and flooded again in late April through early May in preparation for planting to remain wet through harvest in August or September; 3) Sewer ponds -- suitable habitat throughout the year, but small and scattered compared with other wetland habitats (Pt. Reyes Bird Observatory publ.1992).

Wetlands are very important as habitat for wintering shorebirds. Shorebirds need feeding areas in shallow water or on emergent mudflats. Completely flooded wetlands with no edge habitats serve them poorly, as do areas long-since drained and dried. For example, if wetlands are drawn down in late January, shorebirds will find little foraging habitat during the peak spring migration in April. Later draw-down or residual ponds can attract huge congregations of spring migrants to managed wetlands.

By September/October, when water districts and refuges usually begin flooding their lands for ducks and geese, most shorebird movement is past, but some late-migrating species, such as dunlin and long-billed dowitcher, may still make use of managed wetlands.

One shorebird, the western snowy plover, has been eliminated from much of its former breeding range on the Pacific Coast and numbers of coastal breeders appear to be on the decline (Page and Stenzel 1981, Page et al. in prep). Human encroachment of breeding habitat and nest loss to introduced predators are two of the most serious problems currently faced by the plover (SFEP 1991a);

Agricultural Practices

The current agricultural practice of flooding certain annual crops in late summer to control Johnson grass (a forage and pasture grass often considered a weed) produces an important habitat for migrating shorebirds. While the food value of these flooded areas is relatively low, they provide a ponded water habitat that is in short supply elsewhere in the Estuary and is preferred by migrating shorebirds and a few early arriving ducks (Madrone Associates 1980). Modifications to these agricultural practices may severely curtail this important habitat.

Shorebird populations within the Delta are somewhat dependent on and reflect agricultural practices, especially crop patterns and field flooding. Extensive early fall and spring flooding of plowed fields can result in large concentrations of shorebirds (D. Gifford, DFG pers comm. in SFEP 1991a). Shorebird populations are affected by agricultural practices in ways similar to those experienced by waterfowl (discussed above).

Water Diversions and Water Quality

Concentrations of shorebirds differ within the San Francisco Bay region and Sacramento-San Joaquin Delta. The availability of invertebrate prey on tidal flats and the availability of high tide foraging habitat are probable reasons for fluctuating populations. At high tide, shorebirds leave the mudflats to roost or forage in alternate wetlands or adjacent upland habitats (SFEP 1991b). Lower elevation tidal flats supporting a greater invertebrate biomass are more available to shorebirds in the southern than northern reaches of the Bay (Conomos 1979). Estuarine and Delta tidal flat invertebrates respond to high salinity variability caused by fluctuating freshwater Delta inflow from the Sacramento and San Joaquin Rivers. This instability of the salinity gradient may interfere with the establishment of mature populations of estuarine organisms and cause the biomass of benthic intertidal organisms (shorebird food) to decrease. Salinity is a factor that affects many resources in the Estuary. Control of salinity to the benefit of one resource needs to be balanced against possible detrimental affects on other resources.

COLONIAL WATERBIRDS AND SEABIRDS

Like waterfowl and shorebird populations, most colonial waterbird (those which nest in close proximity to several other pairs, forming a "colony") and seabird populations have experienced population reductions due to habitat alteration and degradation, agricultural practices, water diversions, and water quality. These birds rely on the health of the Estuary for foraging, roosting, and breeding habitat. Water diversions and water quality are important factors presently influencing the Estuary's biological health, which in turn influences the

populations of colonial waterbirds and seabirds.

With expanding human populations and resulting development, sites where colonial waterbirds and seabirds can nest free from encroachment are becoming rare. The reduction in breeding populations of herons and egrets is probably due to the combined effects of predators, human disturbance, intensive incompatible land uses, and contaminants. However, colonial waterbirds, such as the double-crested cormorant and western gull, have shown population increases.

Habitat loss, agricultural influences, and water quality have contributed to the declining status of many species within the Estuary. The following addresses these factors and other factors contributing to the decline for three of those species:

> A major population decline in breeding California brown pelicans led to the brown pelican being listed as endangered. Factors contributing to this decline include eggshell thinning attributable to pesticide contamination, oil spills, human disturbance of breeding colonies, over harvest of its prey, loss of post-breeding roost sites, and fishing gear entanglement (DFG 1989).
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> The California least tern generally forage for small fish in open water near their colonies. In the Hayward and Palo Alto areas, low-salinity salt ponds provide favorable pre-migratory staging sites that are important to foraging California least terns during the post-nesting dispersal period, generally July through August. Besides the effect of human encroachment on California least tern habitat, other long-term threats to the population include the invasion by exotic vegetation of colony sites and increased boat traffic, which leads to the deterioration of foraging habitat in adjacent eel grass beds. Eel grass is the only rooted aquatic plant found in open water, and provides habitat for an abundance of aquatic insects, small fish, and algae.
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> The great blue heron is a permanent resident of California and breeds in the Estuary (Grinnell and Miller 1944). It is sensitive to human disturbance near colony sites and has probably been negatively affected by pesticide use (Jackman and Scott 1975). Important nesting colonies have suffered from the deterioration of vegetation which supported them. For instance, the cutting down of large eucalyptus trees by the Department of Fish and Game as part of the development of a new duck club on Joyce Island in the Suisun Marsh eliminated habitat used by 43 pairs of great blue herons. Also, predation from introduced species (e.g., red fox) in nesting areas has caused colony abandonment by herons, egrets, and terns. (Hothem pers com in SFEP 1991a)

OTHER BIRD SPECIES

Many other bird species found in the Estuary have experienced similar population declines:

The California black rail is critically dependent on a very narrow, high-marsh zone not subject to extreme and frequent tidal action, where insect abundance is greatest and where some fresh water influences may exist (Evens et al. in prep in SFEP 1991a). The major threat to the existence of the rail in California is the loss and degradation of its habitat.

The California clapper rail's optimal habitat and highest population densities have been in tidal salt marshes. Generally, four features characterize preferred habitat for this subspecies; 1) marshes supporting an extensive system of tidal sloughs, providing direct tidal circulation throughout the site; 2) predominant coverage by pickleweed with extensive stands of Pacific cordgrass in the lower elevation marsh zone; 3) high marsh cover consisting of tall stands of pickleweed, gumplant, and wrack (washed ashore aquatic vegetation); and 4) abundant invertebrate populations, especially the introduced Atlantic mussel and a particular crab found in mid to low intertidal bays. Clapper rail numbers may be influenced by increased freshwater flows through the Napa Marshes, which likely affects the availability of suitable clapper rail habitat. Other factors possibly related to the decline in clapper rail densities include: elevated levels of trace elements such as selenium from oil refineries; predation by introduced predators such as the red fox; loss of adjacent high marsh areas to various types of development and fill; channel dredging on mudflat foraging areas; and other human disturbances.

The availability of suitable roosting sites for the greater sandhill crane, characterized by wet meadows, is influenced by agricultural practices and weather conditions. Encroachment of urban development threatens to eliminate pasture land and open fields important to wintering greater sandhill cranes. The influence of agricultural practices on waterfowl, described earlier, also holds true for the greater sandhill crane. If the production of corn, the preferred carbohydrate food source for the crane in the Delta were to be reduced in response to agricultural market forces, conversion of agricultural land to other land uses, or loss of sufficient quantity or quality of water in Delta channels, the resulting loss of foraging habitat could affect populations of the crane. To date, the quality and quantity of water on Delta channels has been protected by Delta standards and it is important that the habitat factor be considered in future water quality standard setting proceedings.

Also, the potential conversion of Delta islands to water storage reservoirs is a new threat to the sandhill crane, which would further eliminate available habitat. Habitat destruction, human disturbances, predation, and mower caused mortalities, when these impacts have not been mitigated, have contributed to the listing of the greater sandhill crane as a state threatened species.

Factors affecting the salt marsh yellowthroat's numbers are primarily the loss of tidal salt, brackish, and freshwater marshes around the Estuary. This has drastically reduced the salt marsh yellowthroat's breeding and wintering habitats. Continuous corridors of

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salt marshes, grading upstream into adjacent brackish/freshwater marshes, have been fragmented through creation of salt ponds, stream alterations, agricultural conversion, and urban development. These impacts have made successful dispersion of fledglings and seasonal movements by adults more difficult (Hobson et al. 1985). Reductions in freshwater inflow from adjacent creeks and rivers also negatively affect the population because there is a reduction in the abundance of marsh vegetation and insects that the salt marsh yellowthroat requires for survival (Foster 1977).

The Suisun song sparrow's status is negatively impacted by threats similar to those in other areas around the Bay affecting species dependent on tidal marshes. They include: habitat fragmentation, which creates genetic isolation of subpopulations; lack of high marsh nesting cover, which results in greater vulnerability to tides and predation; toxic contaminants; commercial and residential development adjacent to tidal wetlands; general pollution; and human disturbance. As with other species, further reduction in freshwater outflow from the Delta could adversely impact the quality and quantity of Suisun song sparrow habitat (Larsen 1989). In addition, continual levee projects could have the long-term effect of precluding the establishment of future colonizing sites and thus limit the species' eastern most range.

The tri-colored blackbird's population decline is attributed to the loss of wetlands, which has drastically reduced available nesting and foraging habitat. This has resulted in smaller colonies, which are more vulnerable to disturbance by natural predators and also less able to compete with other species for limited nesting habitat. Pesticides, poisoning (either deliberate or indirect), and increased disturbance by humans also have been cited as contributing to smaller tri-colored blackbird populations.

The bald eagle is a winter resident in the Estuary. Factors impacting bald eagle populations in California are primarily related to human activity: shooting, poisoning, tower and powerline collisions, and depressed reproductive rate resulting from pesticide ingestion.

For the Swainson's hawk, the loss of nesting and foraging habitat to Delta bank protection measures, urban and agricultural expansion, and conversion to unsuitable crops (e.g., vineyard, orchards, rice) continues to present the major threat to its populational stability in the Central Valley (DFG 1989). The conversion of Delta islands to water storage reservoirs also would lead to the probable loss of potential nesting habitat and existing foraging habitat for the Swainson's hawk, if these impacts were not mitigated.

Some agricultural practices and general urban development within and along the borders of the Estuary have led to wetland habitat alterations decreasing wildlife habitat values and impairing the remaining wetlands' functional utility.

The manner in which levees and their vegetation are managed, particularly where land

surface and water meet to form potential marshes and riparian corridors, affects the value of the levees for wildlife. Currently, maintenance practices are directed toward flood prevention and are generally detrimental to maintaining good wildlife habitat conditions. Thus, typical levee maintenance practices have had and continue to have a devastating effect on riparian vegetation and associated wildlife.

MAMMALS

Habitat requirements at various life stages of mammals can vary from generalized to highly specialized. Conversion and degradation of wetland and aquatic habitat are major causes of the Estuary's population decline of mammals. For example:

> The salt marsh harvest mouse is unique to the salt and brackish marshes of the Estuary. The major threat to the salt marsh harvest mouse is destruction and degradation of its habitat. Destruction of habitat has occurred through the diking of tidal marshes, increases in land subsidence from groundwater extraction, and shoreline erosion. Preferred habitat is mid- to higher-elevation tidal wetlands and adjacent transition zones which provide refuge during high tides. Pickleweed may be the dominant vegetation in this area, but a diverse mixture of annual and perennial herbaceous vegetation often characterizes the transitional habitat frequented by the salt marsh harvest mouse (Shellhammer et al. 1982, Shellhammer 1989). Salt marsh harvest mice also may move from tidal and diked marshes to adjacent grasslands in late spring for limited periods of time (Geissel et al. 1988). Upland grasses also provide an important food source for the salt marsh harvest mouse. Further threats to the salt marsh harvest mouse population occur in areas that are proposed for urban development or are susceptible to flooding, and some duck club acreage that is regularly and extensively disced to reduce pickleweed growth. Other populations experiencing similar declines in numbers as a consequence of the same impacts are the Suisun ornate shrew and the salt marsh wandering shrew.
>
> The loss of habitat also affects the riparian brush rabbit. Riparian brush rabbits are limited to areas of dense herbaceous vegetation such as blackberry bushes. As with other species habitat loss is the primary factor threatening the riparian brush rabbit. This habitat loss occurs particularly from agricultural clearing, which fragments, isolates, and limits the populations to marginal areas. Periodic flooding may completely inundate the species remaining habitat as well. Other factors threatening the species include off-road vehicle use and burning that also may reduce and could eliminate an isolated population. Like the riparian brush rabbit, the San Joaquin Valley woodrat and the San Francisco dusky-footed woodrat face similar threats.

Loss of upland areas to urban and agricultural development has also eliminated preferred breeding habitat for common species such as the raccoon, stripped and spotted skunks, and grey fox.

AMPHIBIANS AND REPTILES

Within the Estuary, widespread agricultural conversion and urbanization have reduced or destroyed much of the habitat previously used by amphibians and reptiles for breeding, resting, and foraging. These species inhabit Delta channels, smaller rivers, creeks, perennial lakes and ponds, riparian corridors, grasslands, and seasonal wetlands. Populations of the following species have experienced, or are experiencing, population declines from habitat loss, poisoning, predation, and water management impacts:

The California tiger salamander's habitat has declined greatly, especially in the northwestern and southwestern parts of the Delta as a consequence of agricultural conversion and development (Bury 1972). In addition to habitat destruction affecting the species, rodent poisoning campaigns have successfully decreased the number of rodents which create burrows used by the salamander (M.Jennings pers com in SFEP 1991a).

The California red-legged frog's preferred habitat is willow-lined water courses with moderate to deep pools approximately 3 feet deep, surrounded by thick emergent vegetation providing escape cover (Hayes and Jennings 1989). Factors that may have accelerated declines in populations of red-legged frogs range from excessive harvesting in the late 1800s to the introduction of the bullfrog (Moyle 1973) and predatory fish (Moyle 1973, Hayes and Jennings 1986, 1989). The ongoing loss of wetland habitat continues to make population recovery of this species problematic.

The foothill yellow-legged frog has experienced adverse effects related to current watershed management practices that reduce streamflows and riparian vegetation. The resulting increase in ambient water temperature in riverain systems is detrimental to this species.

As a result of human activity, the giant garter snake and its supporting habitat have been depleted throughout its historic range. Urbanization, recreational development, agricultural development, and grazing of grassland communities has resulted in the destruction of wetlands and the channelization of streams, both essential habitats for the giant garter snake. The species continues to decline throughout its range in the Central Valley as natural sloughs and marshes are eliminated (Brode 1988). Another major factor contributing to the decline in giant garter snake populations has been the introduction of predatory fish (striped bass will eat small snakes) and bullfrogs (Zeiner et al. 1988).

For the western pond turtle, the ongoing loss of suitable nesting habitat may be resulting in inadequate reproduction rates in some areas. Habitat requirements include well vegetated backwater areas with logs for basking, and open, sunny slopes away from riparian zones for egg deposition (M.Jennings California Academy of Science pers com in SFEP 1991a). Extensive water diversions for agricultural and other

purposes have led to the reduction of western pond turtle numbers in California. Dredging also destroys suitable habitat, as does the construction of dams and reservoirs.

INVERTEBRATES

Many insects rely on vegetation found within wetland and upland habitats in the Estuary. The primary threat to insect populations is the loss and alteration of habitat, as exemplified by the valley elderberry longhorn beetle, a special status species. Its habitat is negatively impacted by agricultural conversion, grazing, levee construction, stream and river channelization, removal of riparian vegetation, shoreline rip-rap, urban, recreational and industrial development; and agricultural applications of insecticides and herbicides (SFEP 1991a).

Vernal pools are the natural environment for fairy shrimp, linderiella, and tadpole shrimp in the Central Valley of California. Vernal pools and other ephemeral bodies of water inhabited by these species are imperiled by a variety of human caused activities; primarily urban development, water supply/flood control activities, and conversion of land to agricultural use. Habitat loss occurs from direct destruction and modification of pools from filling, grading, discing, leveling, and other activities. Vernal pools also are indirectly affected by modifications to surrounding uplands that alter the vernal pool watershed.

Rapid urbanization of areas containing vernal pools poses a significant threat to the five species proposed for federal listing: Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, California linderiella, and the vernal pool tadpole shrimp. In the Sacramento area, at least four pool complexes that contained suitable habitat were eliminated by urban development in the late 1980's.

Proposed road construction projects also pose a threat to the vernal pool fairy shrimp, California linderiella, and the vernal pool tadpole shrimp. Vernal pools in the Sacramento area that are inhabited by these species could be adversely affected by the proposed widening of State Highway 16. The State has proposed to extend State Highway 505 from Vacaville to Collinsville in Solano County. This project could directly and indirectly impact vernal pools inhabited by the fairy shrimp and tadpole shrimp species.

Agricultural conversion poses a widespread threat to remaining vernal pools in the Central Valley. In recent months two sites with significant vernal pool in the Sacramento Valley that likely contained the California linderiella, vernal pool fairy shrimp, and the vernal pool tadpole shrimp were plowed or disc and seeded with winter wheat (USFWS 1992). Discing and other farming or ranching practices, including heavy grazing are agricultural practices employed in vernal pools and swales.

Proposed natural gas and petroleum pipelines and electrical transmission lines at these

locales also adversely affect these species. In addition, off-road vehicle use and disposal of waste also adversely affect these species. Activities that reduce the extent of the watershed or that alter runoff patterns may also eliminate the animals, or reduce their population sizes or reproductive success. Vernal pool watershed areas have been reduced by conservation of uplands to paved or grass-turf surfaces, road damming, or other construction activities. Also the presence of summer waters also affects the hydrological patterns. Introduction of water during this time may disrupt the life cycles of these species subjecting them to greater levels of predation by animals requiring more permanent sources of water. Increased water also converts vernal pools to unsuitable marsh habitat dominated by emergent vegetation (USFWS 1992).

PLANTS

Within the Estuary, infrequent flooding, drought, grazing and various human-related disturbances have encouraged the establishment of upland and non-native plants in wetlands. Vegetative disturbances, particularly by livestock grazing, discing of pastureland and urban development have in many cases obscured the boundaries between wetland and non-wetland habitats. The accompanying habitat modifications have resulted in several plant species being state or federally listed. The populations of the following species have experienced or are experiencing a decline in numbers due to losses through grazing, land development and alterations, introduced species, water management practices and recreation in the Estuary. The following discussion profiles the factors affecting these species:

- Habitat of the palmate-bracted bird's beak, consisting primarily of alkali sinks and adjacent upland areas, degraded by off-road vehicle use, trash dumping, discing and grazing.

- Solano grass populations are damaged by road construction, drainage, grazing, and off-road vehicle use. In 1989 the USFWS released a report on a status survey of the Central Valley Orcuttieae, including the San Joaquin Valley Orcutt grass. This report indicated that over 60 percent of the approximately 30 known occurrences of this species have been extirpated, primarily as a result of conversion of suitable habitat to agriculture.

- Many of the Sacramento orcutt grass populations have been eliminated by urban development and resulting hydrologic modifications. Threats to this species include residential development, overgrazing, and conversion to agriculture. Populations are also disturbed by hikers and mountain bikes.

- Slender orcutt grass populations have been affected by the damage or loss of vernal pool habitat as a result of agricultural conversion. Habitat is also threatened by development, over-grazing and changes in vernal pool hydrology.

- Several plant species unique to vernal pools are threatened. The Burke's goldfields population numbers have been affected through urbanzation, conversion of land to row crops, widening along Highway 101, effluent irrigation, and overgrazing by sheep and cattle. Several Sebastopol meadowfoam occurrences are threatened by imminent urbanization since they occur on parcels zoned for residential or commercial use. Indirect effects of urban growth, such as alteration of local and regional drainage patterns, and effluent irrigation also threaten this species. Heavy grazing and off-road vehicle recreation adversely affect populations as well. These effects also influence the Sonoma sunshine population numbers. The westward expansion of the City of Santa Rosa threatens 50 to 70 percent of the remaining Sonoma sunshine habitat. Many of these developmental projects, along with their significant impacts to vernal pool species, have been approved in the Santa Rosa area. Approved mitigation has relied on transplantation into experimentally created vernal pool habitat rather than the preservation of existing habitat. To protect and sustain the populations of vernal pool species, the DFG has been coordinating with the County of Sonoma and the City of Santa Rosa, as well as with other agencies, private landowners and concerned citizens, to protect vernal pools and associated endangered plants in the area since 1989.

- The only existing white sedge habitat, Pitkin Marsh, is subject to persistent development pressures. Any change in the hydrological regime of the marsh, including draining, could threaten the white sedge and other rare plant species there. All of the marsh habitat is privately owned and there is currently no protection for this species.

- Three remaining soft bird's beak populations are threatened by pollution and loss of habitat through developmental pressures. One occurrence of soft bird's-beak is located at Benica State Recreation Area, where a park management plan is being developed. Another site is on DFG land along the Napa River at Fagan Slough, where it may have been damaged by polluted runoff from a municipal water treatment plant. Another occurrence may be adversely affected by residential development. Further studies are needed to determine ecological requirements and factors involved in annual population size fluctuations.

- Near the Calistoga Airport both populations of Napa bluegrass are on private land, and have been reduced by the development of health spas and other construction. Continuing threats include alteration of the hot springs hydrology, early season mowing before flowering or seed set, and potential residential and commercial development. There is no management plan for Napa bluegrass.

- The three existing fountain thistle occurrences are on public land controlled by CalTrans, San Mateo County, and the San Francisco Water District. Construction of Interstate 280 contributed to the decline of fountain thistle by destroying habitat and altering the drainage patterns feeding the seeps in its serpentine grassland plant community. A 1988 fire may have contributed to the destruction of some of the

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populations, but initial reports indicate that they sustained little if any permanent damage. There are no management plans or protection programs for any populations of fountain thistle.

- Of the approximately 20 known occurrences of Delta button celery, about a third have been eliminated by flood control activities and conversion of lowlands to agriculture, including all of the occurrences in San Joaquin County and most in Stanislaus County.

- The factors affecting the Pitkin Marsh lily population are land clearing and draining operations, cattle grazing, and horticultural bulb collecting. Introduced blackberry plants also compete with the lily at Pitkin Marsh. In 1989 the Natural Conservancy entered into voluntary protection agreements with landowners for two confirmed occurrences where safeguards were implemented to protect these populations.

- The two occurrences of the Kenwood Marsh checkerbloom are located on private land and have been adversely affected by nearby housing development, cattle grazing, and agricultural practices, resulting in alteration of local hydrology and elimination of habitat. There are no management agreements with the private landowners. Conservation easements or acquisition of habitat will be necessary to prevent further impacts and alteration of the marsh environment.

- Due to the widespread habitat loss for the Delta tule pea, resulting from the filling and diking of wetlands, its current distribution is largely restricted to fresh and brackish tidal wetlands bordering San Pablo and Suisun bays and tidal wetlands in the Delta. Factors which threatened the populations of Delta tule pea are; agricultural conversion, water diversions, vegetation burning, dredge spoil disposal, recreation, changes in salinity, and levee construction and maintenance all are cited a reasons for the species decline (Niehaus 1977, CNPS 1988).

- Factors leading to the endangerment and decline of Suisun Marsh aster and California hibiscus include the filling or draining of wetland habitats within the plant's range, pollution (oil spills, sewage discharges), and changes in water chemistry from water projects affecting Delta or Bay salinities. Levee maintenance, erosion, and fishing access in high traffic areas are also threats.

- Currently about fifty occurrences of Mason's lilaeopsis are known in the state, but many are expected to be lost because of proposed habitat modifications. The cumulative effect of several proposed projects will combine to threaten this species. These activities include flood control projects (rip-rap), widening the Delta channels for water transport, dredging and dumping of spoils, recreational development, and changes in water quality resulting from decreased flows in the Delta.

WILDLIFE HABITATS AND PLANT COMMUNITIES

Ninety-seven animal and plant species within the Estuary are either endangered, threatened, rare, candidates for listing by state and/or federal agencies, or state species of special concern. These species are either directly or indirectly dependent on wetland and aquatic habitats during some portion of their life cycle. Wetland and aquatic habitat conversion and degradation are major reasons for the decline of the species populations throughout the Estuary.

The alteration and degradation of their habitats also affects many plant species that are significant and crucial components of these communities. The occurrence of special status plant and animal species by community type within the Estuary is presented in Table 1. The most important habitats for special status species in the Delta are associated with tidal salt and brackish marsh, and seasonal.

TIDAL MARSHES

Much of the fragmented or reduced tidal marsh community consists of either small outer bayward edges of historic marshes spared during salt pond construction, or new marshes that were established outside the diked areas following reclamation. These remnant tidal marshes are vulnerable to human disturbance, predators, oil spills, and effluent from water treatment plants and industrial sources. The landward margins of these marshes have lost a significant portion of their natural, higher marsh transition zone, and adjacent upland habitat, and have been transformed into areas consisting of steep dikes with little or no vegetation. The resulting habitat has little cover available for salt marsh dependent species during high tides. This may have resulted in the elimination of some local mammal populations, such as the salt marsh harvest mouse and the salt marsh wandering shrew.

Accelerated conversion of tidal marsh habitat also is attributable to dam construction upstream of the Estuary, which reduces the net amount of sediment transported into the Bay-Delta, affecting rates of erosion and marsh establishment. Historically, any natural erosion that occurred was compensated by simultaneous landward expansions of the marsh plain. However, diking of the marshes and urban encroachment now precludes this from occurring.

The decline of the salt marsh bird's-beak has been caused by modification of its original salt marsh habitat through land filling, dredging for marinas, creation of levees and roads, dredge spoil dumping, and off-road vehicle use.

Mason's lilaeopsis is usually found on saturated clay soils that are regularly inundated by waves and tidal action. Many Mason's lilaeopsis are expected to be lost in the future because of several proposed projects. Impacts affecting the Mason lilaeopsis populations are: flood control projects (rip-rap); widening of Delta channels for water transport; barriers in the Delta which alter the normal tidal regime; dredging and dumping spoils; recreational

development; and changes in water quality from decreased Delta inflows.

SEASONAL WETLANDS

Vernal Pools

Vernal pools provide wildlife habitat similar to other seasonal wetlands. They are used during winter and early spring as loafing and foraging habitat by migratory and wintering waterfowl. Late-drying vernal pool complexes provide brood habitat for species of shorebirds and waterfowl. More than 200 plant species are known to live in vernal pools, 91 percent of which are considered California natives (Holland 1988). Within the Estuary, Solano grass (a federal and state endangered species) and Colusa grass (a State listed endangered species), Contra Costa goldfields, Legenere and bearded allocarya (all federal candidate species) are associated with vernal pools found in areas surrounding the Delta in Solano County. Reclamation for agriculture and urban development have fragmented or destroyed areas where vernal pools and associated plant species existed.

Diked Seasonal and Farmed Wetlands

These wetlands are former tidal areas that are now behind dikes and partially or totally excluded from tidal action. They typically support salt and brackish wetland vegetation. Brackish conditions occur due to dilution by freshwater runoff.

The Suisun Marsh represents over 10 percent of California's remaining wetland acreage and is one of the largest continuous brackish water marshes in the United States. The marsh also comprises the largest diked seasonal wetland complex in the Estuary, extending over 57,310 acres. The Suisun Marsh is a major wintering ground providing a feeding and resting area for waterfowl of the Pacific Flyway and migratory shorebirds. Some of these wetlands are managed privately and some by the State for migratory waterfowl, resulting in extremely variable habitat conditions resulting from varying water salinity management practices.

Brackish water quality within the Suisun Marsh is influenced by both the Sacramento and San Joaquin rivers. Managed wetlands of the Suisun Marsh are diked so that the effects of tidal fluctuations can be better controlled. Large portions of the undiked areas are submerged daily. Parts of higher ground are flooded by seasonal high tides. Most management units are flooded in the fall and drained in the spring. In general, average soil salinities in the

Suisun Marsh are increasing due to factors such as timing, duration, and quality of water available for flooding. Also, salinity changes in Suisun Bay, fluctuating from operations of the state, federal, and other water projects, indirectly affect salinity levels in the marsh.

To maintain the brackish nature of the Suisun Marsh, and to ensure the germination of important waterfowl food plants, it is important to have water of acceptable quality available in late winter and early spring to leach accumulated salts out of the soil. Water too degraded for effective leaching is a continuing problem; critical in dry years. The frequency of high salinity levels in and near the Marsh have increased as Delta outflows have been reduced and altered by increased diversion, use, export, and channel alteration. This trend is expected to continue.

Wildlife habitat in Suisun Marsh, in the absence of a salinity control structure and effective management of the Marsh, would be increasingly threatened by any decline in water quality. During periods of low Delta outflow, the average annual duration of higher salinity levels at the mouth of Montezuma Slough increases. Prior to the completion of the salinity control gates, this high salinity would move into the marsh, and when this occurred during the marsh management season (September through May), it resulted in increased soil/water salinities that discourage the growth of plants providing food for wintering waterfowl. Fortunately, efforts being implemented by DWR and USBR to protect the Marsh with key facilities such as the Suisun Marsh Salinity Control Structure have been successful. Full implementation of the program with the accompanying water quality standards will ensure that the Suisun Marsh's brackish wetland value will be maintained.

RIPARIAN AREAS

Riparian vegetation in the Estuary provides valuable wildlife habitat. At least 107 wildlife species use the riparian woodland regularly. The value of riparian woodlands depends on the plant species, maturity, and diversity of the vegetation. Because some larger trees (cottonwood, western sycamore, white alder, valley oak, and willow) take 30 to 40 years to reach maturity, full replacement of this diverse vegetation, if removed, takes a relatively long time. Moreover, value as habitat during the replacement period is of limited benefit. Flood control and river bank stabilization areas have less wildlife value than Delta sites (Madrone 1980) where riparian vegetation has not been removed.

Natural community losses associated with island levee protection work and intensive management of the Delta water supply impact biodiversity on a national scale and possibly at the global level as well. Evidence of this is illustrated by the increasing numbers of Federal and State listed and proposed endangered, threatened, and candidate species that are unique to

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the region and depend to some degree upon the natural functions of the Delta ecosystem. For example, the Delta button celery inhabits riparian scrub habitat. Loss and alteration of riparian scrub habitat has led to the Delta button celery being listed as a State endangered and Federal candidate 1 species (unlisted but there is biological evidence that could support a proposal for listing). Of the approximately 20 known Delta button celery communities, about a third have been eliminated by flood control activities and conversion of lowlands to agriculture.

OTHER FACTORS AFFECTING WILDLIFE AND PLANT RESOURCES

POLLUTANTS

Primary sources of contaminants in the Estuary include urban runoff, non-urban runoff, riverine inflows from agricultural lands of the Central Valley, discharges from municipal waste treatment facilities, industrial effluent including that from oil refineries, dredging and dumping spoils, and oil spills (Davis et al. 1990). Although few studies have been conducted to determine the specific biological effects of various contaminants on estuarine wildlife, certain links between contaminants and their effects on the ecosystem have been either established or strongly correlated (SFEP 1991a).

In aquatic systems, nitrogen and phosphorus are considered the most critical nutrients because excess quantities of either can degrade water quality and promote algal blooms and the growth of other undesirable plant species (Sather and Smith 1984). Agricultural and urban runoff are the primary sources of phosphorus and nitrogen entering the aquatic system (Van der Valk et al. 1978), and wetlands provide a primary mechanism for the removal of nitrogen from the aquatic environment.

Environmental contaminants known to be present in concentrations that could threaten wildlife populations in the Estuary include: cadmium, copper, mercury, selenium, and silver (Luoma and Phillips 1988, Ohlendorf and Fleming 1988); chlorinated hydrocarbons, including pesticides such as DDT and its metabolites and polychlorinated biphenys (PCBs) (Phillips and Spies 1988); and polycyclic aromatic hydrocarbons (PAHs) (Wright and Phillips 1988). There are many other contaminants present in the Bay ecosystem, but there is insufficient information to relate their presence and concentration levels as threats to the Bay's wildlife resources (SFEP 1991a). Studies conducted from 1986 through 1989 documented increasing trends in selenium levels in wintering diving ducks from San Francisco, San Pablo, and Suisun bays (White et.al. 1989; Urquhant and Regalado 1991). In several instances, measured selenium levels were elevated beyond concentrations known to cause selenium toxicosis and reproductive impairment in water birds.

California's Central Valley is an important agricultural area where about 10 percent of the nation's pesticide tonnage is applied to crops. Although the use of some pesticides has

been banned or restricted, residues will persist in valley soils for some time. These soils will serve as a reservoir for continued leaching and migration of DDT, chlordane, Dieldrin, toxaphene, and other persistent pesticides to the Estuary (Wright and Phillips 1988).

Contaminants may adversely affect wildlife if they reduce the food base or otherwise disrupt habitat required for wildlife survival. Contaminant exposure impacts range from slight changes in nesting behavior to complete reproductive failure. Organochlorines are well known for their detrimental effects on avian reproduction. Exposure to DDT causes eggshell thinning and decreased egg hatchability, a major contributor to the decline of several species of birds in California, including raptors, brown pelicans, and double-crested cormorants (SFEP 1991a).

HUNTING

Hunting affects the number and distribution of wildlife populations in the Estuary, even though it is carefully regulated to prevent serious threats to overall population survival. Hunting also has a beneficial affect in that areas managed for hunting generally provide desirable forage and cover for waterfowl and other game species. Privately operated gun clubs in the Suisun Marsh and the Delta support most of the waterfowl hunting within the Estuary. These clubs use tidal water from major sloughs to manage constructed diked wetlands on former tidal wetlands, primarily as wintering habitat for dabbling ducks and geese. These duck clubs in the marsh produce food plants, provide nesting and breeding areas, and serve as cover and resting areas for waterfowl and other wildlife. These form a valuable adjunct to waterfowl management areas since they are fallow most of the year. The major threat to privately owned wetlands is conversion to other land uses.

Another factor affecting wildlife populations is regulated harvesting of certain wildlife species. Harvest rates of furbearing mammals are set by the Fish and Game Commission and include: badgers, beavers, bobcats, coyotes, gray fox, minks, muskrats, opossums, raccoons, spotted skunks, striped skunks, and long-tailed weasels. Rules establishing take and possession of native species of amphibians and reptiles are established by the Fish and Game Commission as well. Bullfrogs are currently harvested in the Estuary. The western pond turtle, under the state fishing regulations, has a harvest limit of two. Although the turtle is a species of concern, it is not listed. However, in response to concerns over excessive collection of the species, and the anticipation of a state listing, it is likely a proposal will be made to the Fish and Game Commission to prohibit the take of turtles commencing in 1994. (J. Brode pers. comm)

CONCLUSION

The quantity and quality of wintering habitat in the Estuary and the Central Valley is one of the most important factors limiting waterfowl and migrating bird populations. Habitats for waterfowl and other bird species populations are too often converted to other community types or fragmented to the point wildlife populations are distributed in confined areas making them susceptible to disease, predation, and human disturbances. Urban encroachment and agricultural development also threaten wetland and upland habitats. If projected seasonal wetland losses to urban growth or other land conversions become a reality, accompanying reductions in populations of migratory shorebirds and other waterbirds are highly probable.

With the conversion of natural wetlands to agricultural production, migratory waterfowl and other bird species have become dependent on these lands for food. The suitability of wintering habitat is a limiting factor for many Pacific Flyway populations of shorebirds and other bird species. Farms within the Estuary provide resting and feeding areas in the fall, winter, and spring. The value of farmland as habitat for wildlife populations depends on an individual parcel's vegetational characteristics, cultivation practices, and flooding regimes. Irrigation and leaching, subsidence and levee stability, crop selection, clean farming, and harvesting efficiency are all factors which have a relationship to the stability of many wildlife populations.

A decrease in freshwater outflow resulting from increased water diversions, in-Delta consumption, and drought, results in higher salinity levels encroaching further into the Estuary. Increased salinities in the Delta, should they occur in the future, could affect decisions regarding the types of crops grown. However, present regulations and policies to safeguard water quality in the Delta are focused on maintaining salinity levels at concentrations low enough to avert this crop-shifting scenario.

Salinity changes can also alter the distribution of wetlands, resulting in adverse impacts upon preferred forage areas for many wildlife species while benefiting more salt tolerant species. The Suisun Marsh is an example of a valuable wintering area where salinity levels are threatening the existence of brackish marsh plants critical to this community. It is also an example of where, through the implementation of the Suisun Marsh Plan of Protection, a cooperative effort is underway to provide adequate water salinities.

Flood control projects and construction and maintenance of levee and bank stabilization projects reduce or alter flood plains and dependent wetlands. Maintenance practices are directed toward flood prevention and are generally detrimental to riparian vegetation and associated wildlife habitat conditions on the levee slope. Nevertheless, levee systems are critical to maintaining landside wildlife values.

Many factors have affected plant and wildlife populations within the Estuary, resulting in their decline. Some species have been listed as endangered or threatened under the State and/or Federal ESA. Degradation and conversion of habitat is the primary factor affecting the

population status and stability of these species. Riparian communities, which are the habitat of choice for the greatest number of listed species, continue to be eliminated through bank stabilization and flood control efforts. Levee maintenance has created a dilemma of protecting landside values while degrading or reducing levee riparian and heavily shaded aquatic communities. Flood control projects, combining upstream diversion and storage of streamflows and rip-rapped levees in the Delta, have substantially reduced the volume and timing of freshwater in-flows and the transport of beneficial sediments and nutrients that feed downstream wetlands and overflow areas. Special plant species associated with wetlands which have been substantially eliminated or converted are experiencing a decline in numbers similar to that associated with wildlife populations.

Preservation of remaining wetlands and riparian habitat, and ultimately increasing the acreage of those habitats, is the most important and effective action that can stabilize and reverse overall ecological declines in the Estuary's populations of many plant and animal species. Important positive steps to preserve and increase wetland and riparian habitat have already been taken. These include the Suisun Marsh Preservation Act, the Suisun Marsh Plan of Protection, BCDC activities and the establishment of the Consumnes River Preserve and other local management areas and preserves.

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